علوم محیطی سال ششم، شماره چهارم، تابستان ۱۳۸۸
ENVIRONMENTAL SCIENCES Vol.6, No.4, Summer 2009
19-28

Water Quality Assessment of Gheshlagh River Using Water Quality Indices

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Abstract
Comprehensive information and knowledge about the quality of water resources plays a very important role in preservation plans for water resource management. One of the engineering methods used to assess river water quality conditions without mathematical and statistical complexity is water quality indices. In this method, different water quality parameters are analyzed and interpreted in a river water quality assessment study. It is one of the most important parts of river quality monitoring plans in which the qualitative indices are converted to a single and dimensionless number. Water quality classification is undertaken on the basis of the value of the indices comparing with a predefined rated scale. In this study, a monitoring plan is achieved for the 18 stations located along with Gheshalgh River in Kurdistan province in Iran. Water quality assessment has been conducted using two NSF quality indices of general water use and the British Columbia index for drinking and agricultural consumption. Based on the results obtained from these indices, water of this river has the worst quality due to agricultural use downstream of the wastewater treatment plant of Sanandaj city. Its condition is degraded up to the discharge point of Morghe Par slaughterhouse due to the assimilation capacity of the river. In this location water quality is acceptable for drinking purposes and most of the stations have appropriate conditions except for Dare Kuleh and the downstream station which are on the border. Results indicate that the degree of influence of urban pollutant sources such as entry of urban wastewater and also of a landfill leachate brook is high, especially in the Gheshlagh bridge area up to the tributaries.

Keywords: water quality index, NSF, BCWQI, wastewater, Iran, Kurdistan.

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بررسی کیفیت آب رودخانه قشلاق با استفاده از شاخص‌های کیفی آب

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چکیده
اطلاعات کافی و آگاهی از کیفیت منابع آب در حفظ این منابع و همچنین در برنامه‌ریزی‌ها و مدیریت منابع آب بسیار حائز اهمیت است. یکی از روش‌های مهندسی و به دور از پیچیدگی‌های ریاضی و آماری که می‌تواند شرایط کیفی آب را بازگو نماید استفاده از شاخص‌های کیفی آب است. تحلیل و تفسیر انواع پارامترهای مورد اندازه‌گیری در طول محدوده مورد مطالعه از رودخانه یکی از مهم‌ترین قسمت‌های طرح‌های پایش کیفی رودخانه یا طرح‌های جامع کاهش آلودگی رودخانه می‌باشد. با استفاده از شاخص‌های کیفی حجم زیاد اطلاعات نمونه برداری شده، از اندازه‌گیری‌های کیفی آب به صورت یک عدد منفرد و بدون بعد تبدیل می شود که این عدد در یک مقیاس درجه بندی شده، دارای مفهوم و تعریف کیفی تفسیر شده‌ای است. این تحقیق بر اساس نتایج اندازه‌گیری شده در ۱۸ ایستگاه در طول رودخانه قشلاق در استان کردستان می‌باشد که به صورت جداگانه با استفاده از دو شاخص کیفی NSF برای مصارف عمومی آب رودخانه و شاخص بریتیش کلمبیا برای مصارف شرب و کشاورزی صورت گرفته است. بر اساس نتایج حاصل از این شاخص‌ها آب رودخانه برای مصارف کشاورزی در ایستگاه خروجی تصفیه خانه فاضلاب شهر سنندج به رودخانه دارای بدترین کیفیت می‌باشد که ایستگاه‌های پایین دست خود را نیز تحت تاثیر قرار می‌دهد، این وضعیت کیفی، تا پایین دست خروجی کشتارگاه مرغ پر به داخل رودخانه،که با توجه به قدرت خودپالایی رودخانه کیفیت قابل قبولی حاصل می‌گردد ادامه دارد. برای مصرف شرب نیز اکثر ایستگاه‌ها دارای شرایط مناسب بوده و ایستگاه‌های دره کوله و پایین دست شاخه فرعی سو در شرایط مرزی می‌باشند. نتایج نشان دهنده میزان اثر گذاری بالای منابع آلاینده شهری اعم از ورود فاضلاب شهری و ورود نهر شیرابه مدفن زباله شهری بر کیفیت رودخانه در بازه‌های پل قشلاق تا شاخه فرعی سو می‌باشد.

کلیدواژه‌ها: شاخص کیفی آب، NSF ، BCWQI ، رودخانه قشلاق، فاضلاب.

Introduction

Preserving the quality of water resources for drinking water, encouraging recreational activities and uses and creating a proper ecosystem for fishing and wildlife require a high quality of river water. In this regard, determining water quality parameters is important to diagnose the quality, conditions and pollution level of surface waters. Therefore related data must be processed and the results must be presented to specialists. One of the simplest methods to assess water quality conditions is by using water quality indices (Ministry of Power, 2005).

Indices simplify and reduce the required raw and primary date for describing water quality and its spatial variation can show the particular water quality problems within a river body, allowing for many managerial decisions to be made. In a simple definition about indices it can be said that indices are proper and simple tools to determine conditions of water quality and, like any other tool, this requires knowledge about principles and basic concepts of water and related issues (Nikbakht, 2004).

Many environmental indices have recently been suggested by different organizations and institutes, so that at the last decade of the 20th century much interest has been created to improve control water quality indices. One of the methods that has led to an improvement over the old indices is the comparison of these indices with each other. In this regard, the first comparison among quality indices of water was conducted by Ott in 1971; he compared two indices which had been created by Landor and Deninger and revised the quality indices in USA. Two indices which were presented by them belong to general and particular consumption indices. Such research has also been conducted in European countries. Brokel and Helmond proved through the results of their research about environmental indices that around 30 indices can be applied throughout the world to classify water quality. They showed that all indices include between 3 to72 variables which have been selected from NH_4+N, PO4 + P, NO_3+N, PH and total solid (Ramirez and Solano, 2004).

Due to the importance of this issue, many studies and research projects have been conducted on this issue worldwide such as the indices which Stenbak Gelizhanof created in 1999 in Croatia and indices created in 1994 in southern Africa by Koper and by Richardson in 1997 as well as in Australia in 1998. Significant developments in creating quality indices have been made in Central America by Leon and Richardson (Ramirez and Solano, 2004). Presently, many research projects and studies are being conducted with this method to create quality indices for water. In Iran water quality indices are under consideration too, such as the research conducted by Tajrishi and Norouzian in 1998 using a fuzzy-classification technique on the Karoon and Dez rivers whereby these rivers were zoned qualitatively (Norouzian, 1998; Parvizi *et al*., 2004).

The basin of Geshlagh River is located to the North, South and East of Sanandaj city. Gheshlagh River is one of the main four tributaries of Sirvan River which extends as Dialeh River and enters to Dar Bandkhan Lake in the Kurdistan area of Iraq (Tehran University, 1997). Gheshlag River in Hadi Abad village in the south of Sanandaj city reaches to Gaveh or Gavehroud River and constitutes the main and eastern tributary of the Sirvan River. This river is 95 km long in its bed and its watershed is around 1850 km^2 based on Yelieh station. Before it reaches Gaveh, the River Geshlagh consists of 17 small tributaries with the length of 10-25 km. Along the river from upstream of Geshlagh dam to the north of Sanandaj city, wastewater from the surrounding villages enters it until after the egression of Geshlagh dam where there is a concentration of industrial towns, or a little lower down where the main sewage of Sanandaj city enters it, and the river receives all pollutants and wastewaters.

Materials and Methods

To analyze and interpret the kinds of parameters measured along the range of a river, there are various mathematical methods that are used such as water quality index. It is one of the simplest methods with wide applications. In this method a considerable amount of data resulting from measurements of water quality are converted to a single and dimensionless number in a rated scale with interpreted quality and conception.

In general, water quality indices are divided into five main groups (Sobhani, 2003):

A) Public indices: in this category, the indices ignore the kind of water consumption in the evaluation process, such as NSFWQI, Horton (Ott, 1978) (Horton, 1965).

B) Specific consumption indices: in this category, classification of water is conducted on the basis of the kind of consumption and application (drinking, industrial, ecosystem preservation etc). The most important and applicable of these indices are the Oconer, Oregan and British Columbia indices (DEQ, 2003).

C) Statistical indices: in these indices statistical methods are used and personal opinions are not considered.

D) Designing indices: this category is an instrument aiding decision making and planning in water quality management projects.

Among the public water quality indices, NSF is the most applicable index in this regard. On the other hand, the parameters considered in this index are mostly the parameters that are measured in the river water quality monitoring programmes and environmental assessment (Zandberg and Hall, 1988). Also, the British Columbia index is a more appropriate index as it considers water usage criteria. This index has been used in this research on river water quality assessment for drinking and agricultural consumptions.

Mathematical Structure of Quality Indices

Two main and primary forms exist for indices:

- Indices whose index number increases with increases in the pollution level and are known as pollution indices.
- Indices whose index number decreases with increases in the pollution level and are known as qualitative indices.

In a general framework, calculating an index has two main stages: (1) estimating sub-indices based on water quality variables used in the index and (2) summing these sub-indices to obtain a general index.

British Columbia Water Quality Index

British Columbia quality index was developed by the Canadian Ministry of Environment in 1995 as increasing index to evaluate water quality. In this method, water quality parameters are measured and their violation is determined by comparison with a predefined limit. This limit can includes recommended guidelines to keep to suitable levels of water utilization. One of the advantages of this method, is the use of standards for each area or country and so provides possibility to make a classification on the basis of all existing measurement parameters.

To calculate final index value the following equation is used:

$$BCWQI = \left[\sqrt{\left(F_1^{\,2} + F_2^{\,2} + \left(\frac{F_3}{3} \right)^2 \right)} \right] \Big/ 1.453$$

F1: percentage of parameters which have been violated with respect to all parameters

F2: number of offender data with respect to all measured data

F3: maximum percentage of violation

The number 1.453 was selected to give assurance to the scale index number from zero to 100. It is important to note that repeated samplings and increasing stations increase the accuracy of British Columbia index. The disadvantages of this method are that this index does not indicate the water quality trend until it deviates from the standard limit. Also, due to using a maximum percentage of deviation, it can not determine the number of withdrawals above the maximum limit of standard (Ministry of Environment, 1996). Table 1 shows the rankings in the British Columbia water quality index.

NSF Water Quality Index

A Water Quality Index for the United States of America was developed by the National Sanitary Foundation (NSF) in 1970 to monitor the variation trend in river water quality. It has been used throughout the USA by the executive agencies. This index represents the general water quality status of monitoring stations using 9 quality parameters. This index has the capability of being estimated using existing data from water quality parameters, if data for some parameters are lost. Parameters that are required for this index are as follows: fecal coliforms, $B0D_5$, turbidity, pH, TSS, D0%, $N0_3$, $P0_4$ and ΔT. Measured parameters according to the sub-index of each of them are achieved on conversion curves. Then, to estimate the final index the following equations are used (NSF, 2003):

$$1) I=\sum_{i=1}^{n} I_i \times w_i$$

$$2) \sum_{i=1}^{n} W_i = 1$$

I_i= Sub-index of each parameters

W_i= Weighting factor

n= Number of sub-indices

Table 2 shows the ranking criteria of NSF water quality index and, in Table 3, the weights of the water quality parameters are presented.

Table 1- Water quality ranking for british columbia water quality index.

Rating	F_1	F_2	F_3	Index Value	Index Rank
Excellent	0 to 2	0 to 1	0 to 9	0 to 4	0 to 3
Good	3 to 14	2 to 14	10 to 45	5 to 25	4 to 17
Fair	15 to 35	15 to 40	46 to 96	26 to 62	18 to 43
Borderline	36 to 50	41 to 60	97 to 99	63 to 85	44 to 59
Poor	51 to 100	61 to 100	99.1 to 100	86 to 145	60 to 100

Table 2- NSF water quality index ranking.

Quality	Value
Very good	90-100
Good	70-90
Fair	50-70
Bad	25-50
Very bad	0-25

Table 3- Importance rate and parameters weight in NFSWQI.

Parameters	Weight
Do%	**0.17**
Fecal Coliform	**0.16**
pH	**0.11**
BOD_5	**0.11**
ΔT	**0.1**
$T.PO_4$	**0.1**
NO_3	**0.1**
Turbidity	**0.08**
TS	**0.07**

The study area includes 18 stations for quality monitoring along with river; the specifications of these stations are given in Table 4.

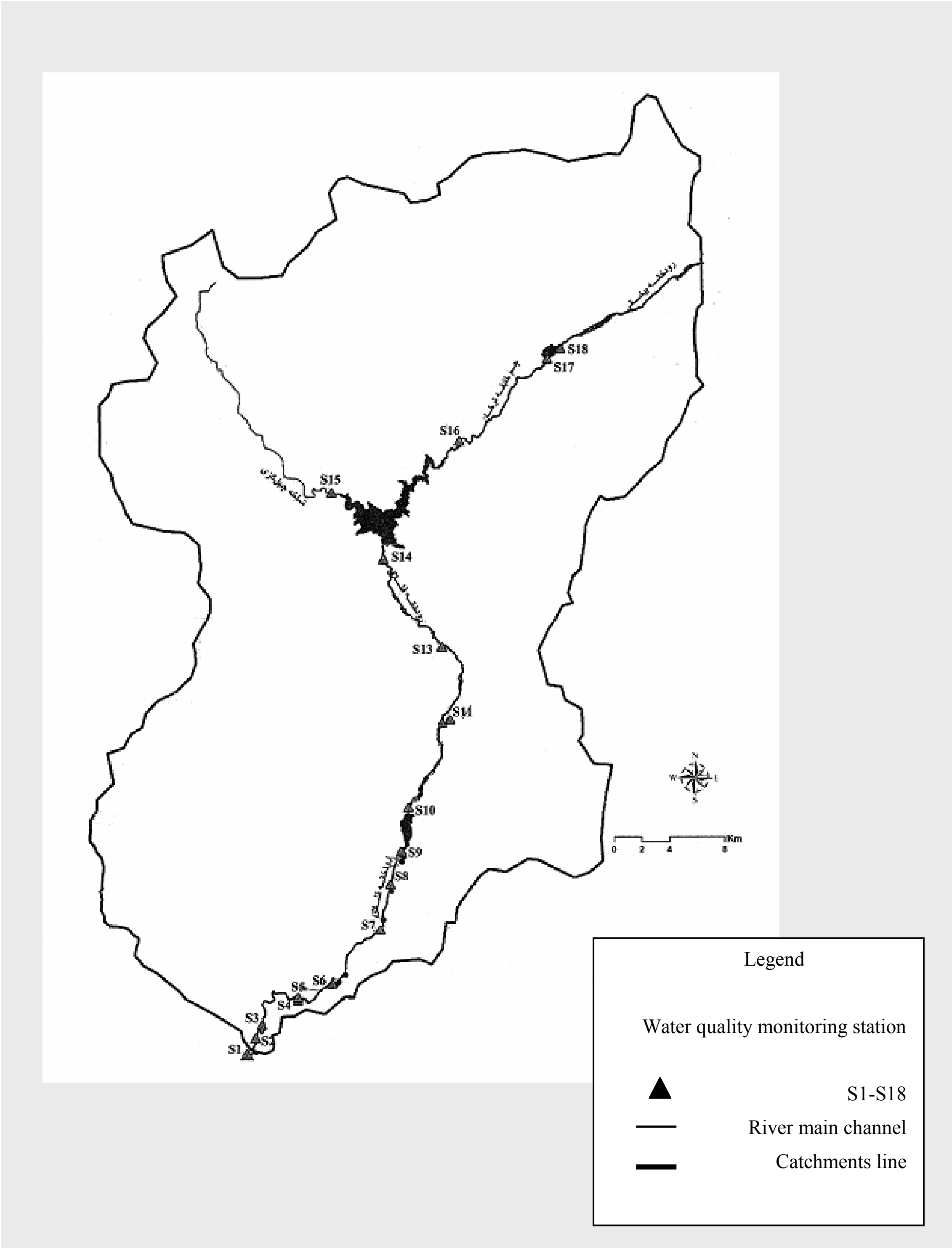

Figure 1. Confirmation of stations in Gheshlagh river.

Table 4- The situation and the name of monitoring stations in the study areas.

Name of stations	Elevation (m)	Distance from downstream(Km)
After the Coincidence of Gavrood and Gheshlagh (S1)	1326	0
Dare Koole station (S2)	1293	1.8
Darvishan Tributary (S3)	1302	3.25
After the Coincidence of Soo Tributary (S4)	1311	8.65
Soo Tributary(S5)	1313	10.5
Downstream of Slaughterhouse Discharge(S6)	1332	12.05
After the Coincidence of landfill leachate and Gheshlagh (S7)	1357	17.55
Downstream of Sanandaj Wastewater Treatment Plant (S8)	1362	20.95
The Coincidence of Sanandaj Wastewater and Gheshlagh (S9)	1373	22.5
Downstream of Baharan WW and Gheshlagh Coincidence (S10)	1390	26.65
Salavat Abad Tributary (S11)	1422	30.5
Gheshlagh Bridge (S12)	1419	33.45
Vahdat Fishery Upstream (S13)	1447	39.45
Gheshlagh Dam (S14)	1479	47.45
Chehelgazi Station (S15)	1567	53.35
Khalife Tarkhan Station (S16)	1574	61.2
Downstream of Hosseinabad Village (S17)	1661	72.2
Upstream of Hosseinabad Village (S18)	1687	73.63

Water quality parameters were measured over a one-year monitoring period in 2008-2009 and were sampled in September, December, March and June. In Figure 2 the values of the final index for each station have been shown separately based on measuring results in the water year considered.

When considering Figure 2 it is observed that, based on comparing British Colombia index with the drinking water standards of the World Health Organization in 2006, only station No.18 as the upstream station shows suitable quality conditions. Most of the stations are within proper range. Stations 2 and 4 are located in the middle range.

According to the British Columbia quality index for agricultural consumption (Fig.3), stations 1, 2, 3, 5, 11, 12, 13, 15, 16 and18 are located in an excellent range for agricultural purposes and stations 6, 7 and 8 which are located within an area of industrial concentration are not proper for agricultural purposes. Station 9 is the most polluted area for agricultural use due to the discharge of urban wastewater into the river.

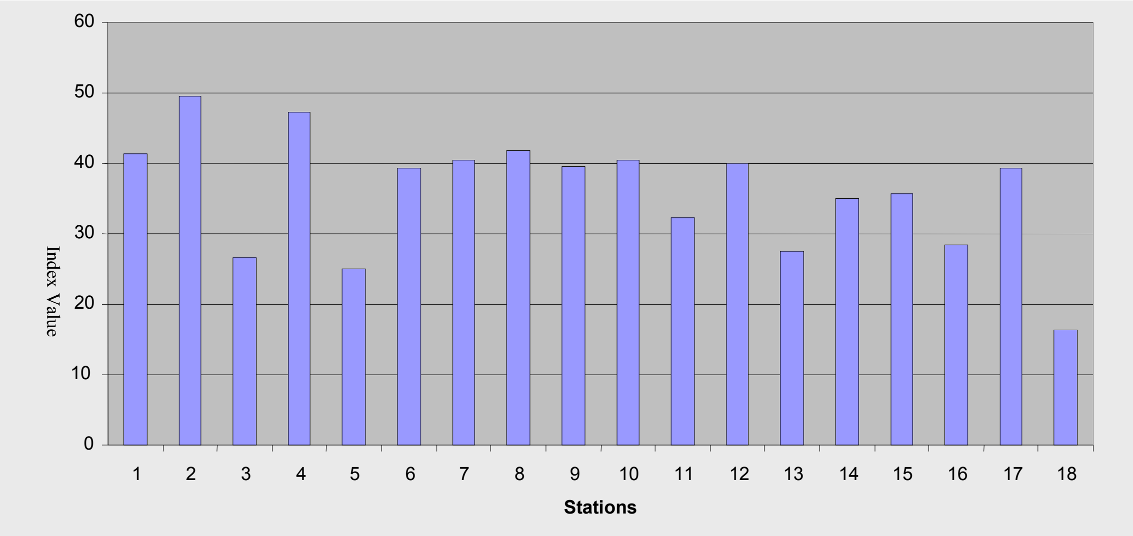

Figure 2. Diagram of British columbia WQI for 2008-2009 for drinking water consumption.

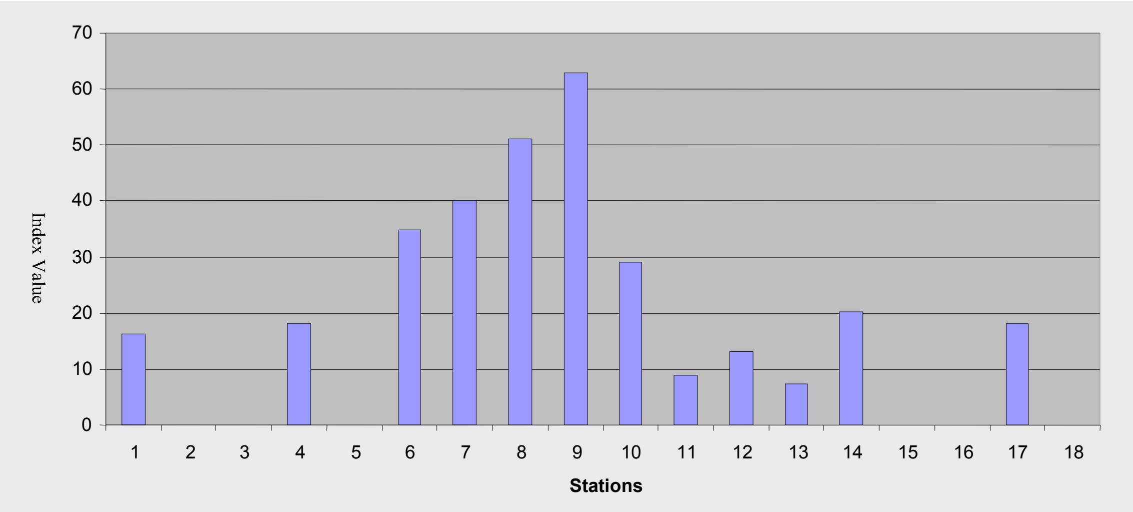

Figure 3. British columbia water quality index for 2008-2009 for agricultural consumption.

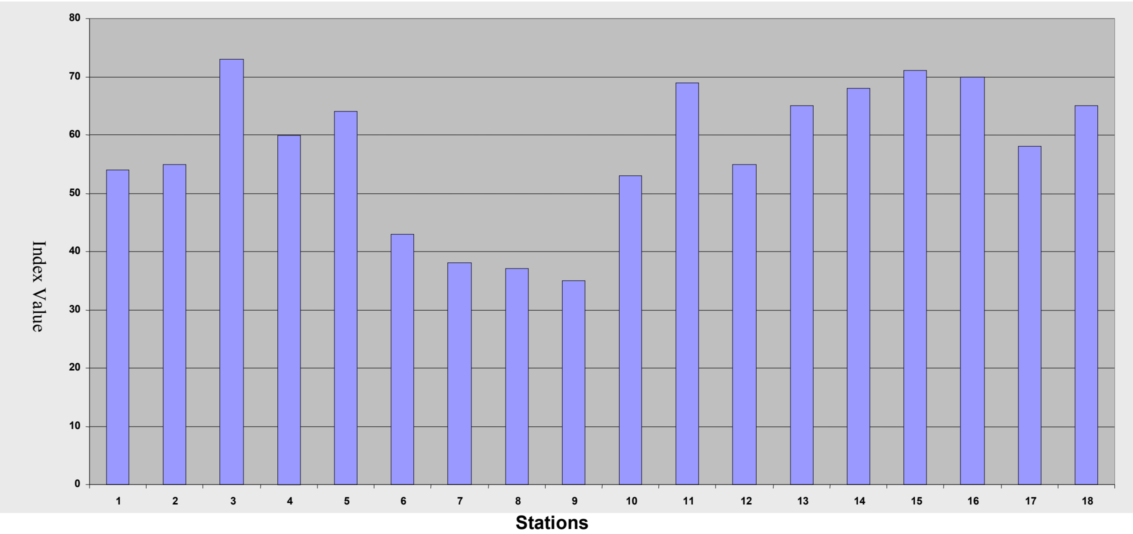

Figure 4. NSFWQI diagram for the dry season (summer).

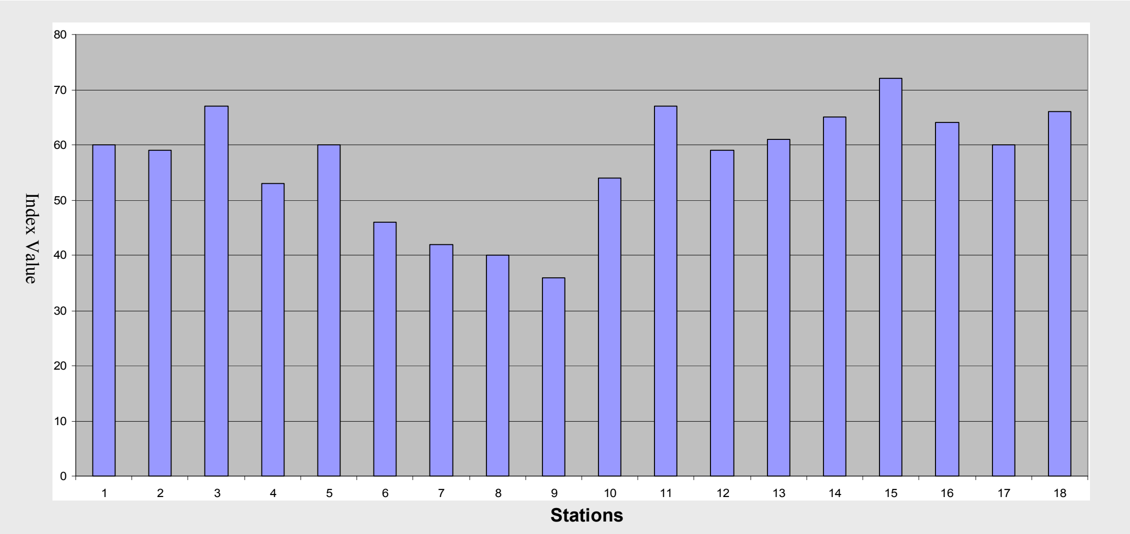

Figure 5. NSFWQI diagram for the wet season (spring).

As shown in Figures 4 and 5, the situation of water quality in both the two season shown (dry and wet seasons) are the same. In each season, stations No.6, 7, 8 and 9 are in a poor status and the most important reason for this pollution status is the discharge of Sanandaj's wastewater into the river.

Discussion and Conclusion

Due to the lack of expert study and inspection of the water quality of most rivers of Iran, using water quality indices for particular consumption is considered as a simple method for the primary recognition of river water quality. Due to qualitative evaluation along the river, all the urban wastewater of Sanandaj city enters the Gheshlagh River at station 9. Furthermore, industrial wastewater from the industrial towns 1 and 2 of Sanandaj is observed entering the river between stations 9-13. In most seasons, especially in the dry seasons, the assimilation capacity of the river becomes a weakness in this situation. But river water is appropriate for agricultural consumption at most stations except for the slaughterhouse and Morghe-par downstream stations and after the confluence of landfill leachate and the Gehshlagh with urban wastewater. According to the aforementioned issues, to improve the river water quality it is necessary that the relevant authorities build a wastewater treatment plant for Sanandaj city and, because of an intense reduction in the dissolved oxygen downstream of the industrial complex, manufacturing re-aeration structures such as concrete spillways in the river can contribute to promote its power of self-purification.

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